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(71) Applicants
So "Resprom"
(Incorporated in Bulgaria)
1 K. Ptschelinski St, Sofia, Bulgaria
UkrNiishom
(Incorporated in USSR)
201 Prosp. Gagarina, Kharkov 80, Union of Soviet Socialist Republics

(72) Inventors
Kalin Vassilev Karov
Ludmil Antonov Petrov
Oleg Grigorievitch Tibabtchev
Dimiter Todorov Boykov
Igor Nikolaevitch Serebriakov
Nina Toleva Genova
Boianka Ivanova Bakalova
Penka Boteva Ivanova
Dimiter Vesselinov Tersiev
Viktor Evstatiev Pelov
Boyidar Nikolov Boykov
Vladimir Moiseevitch Skoropad
Alexander Savelievitch Kachurko
Yuri Ivanovitch Feodorov
Mitko Ivanov Todorov

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(74) Agent and/or Address for Service
Haseltine Lake & Co
Hazlitt House, 28 Southampton Buildings, Chancery Lane, London, WC2A 1AT

(54) **Colour sensor for crop indentification**

(57) The sensor comprises a light source (12) and a block containing a light separation element (3), and photodetectors (5) and (4) for detecting respectively radiation in the visible part of the spectrum and in the infrared part of the spectrum adjacent the visible part from light reflected by objects (6) in the zone of viewing. The outputs of the photodetectors are connected through respective linear amplifiers (7) and (8) to the inputs of a comparator unit (11) whose positive or negative output is the output of the colour sensor. The output of amplifier (8) is summed at (9) with the output of a DC voltage source (10) to allow the sensor to discriminate between plants and rocks viewed against a light or dark soil.

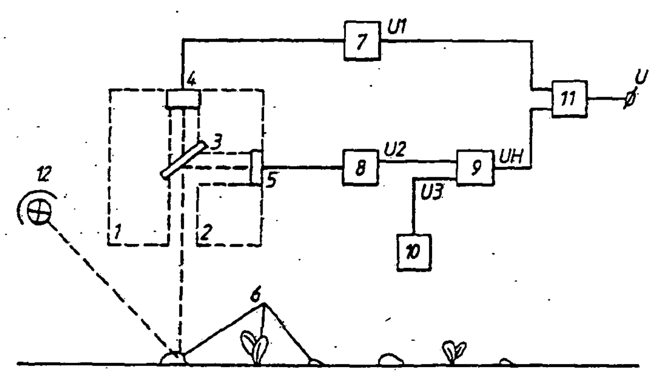

FIG.1

The drawing(s) originally filed was (were) informal and the print here reproduced is taken from a later filed formal copy.

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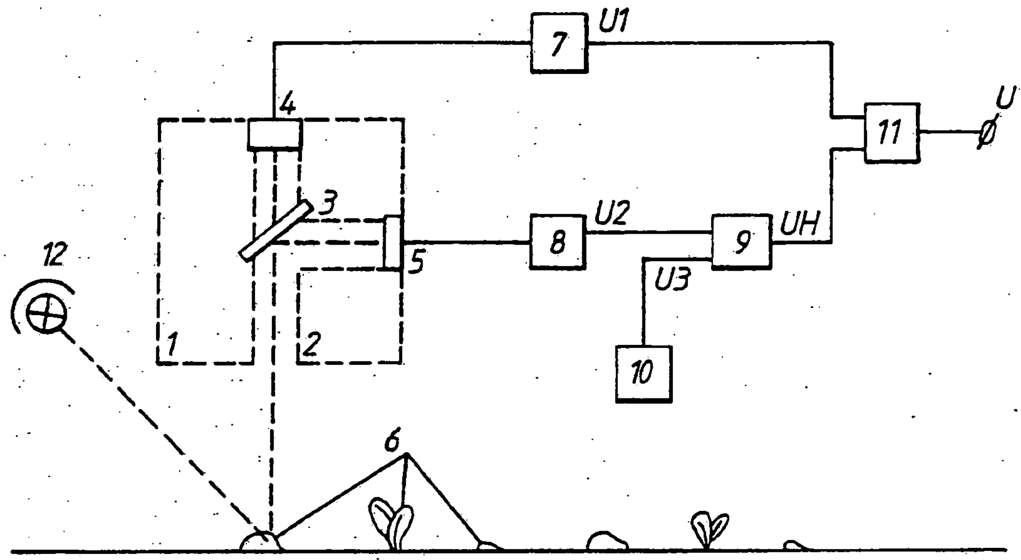

FIG.1.

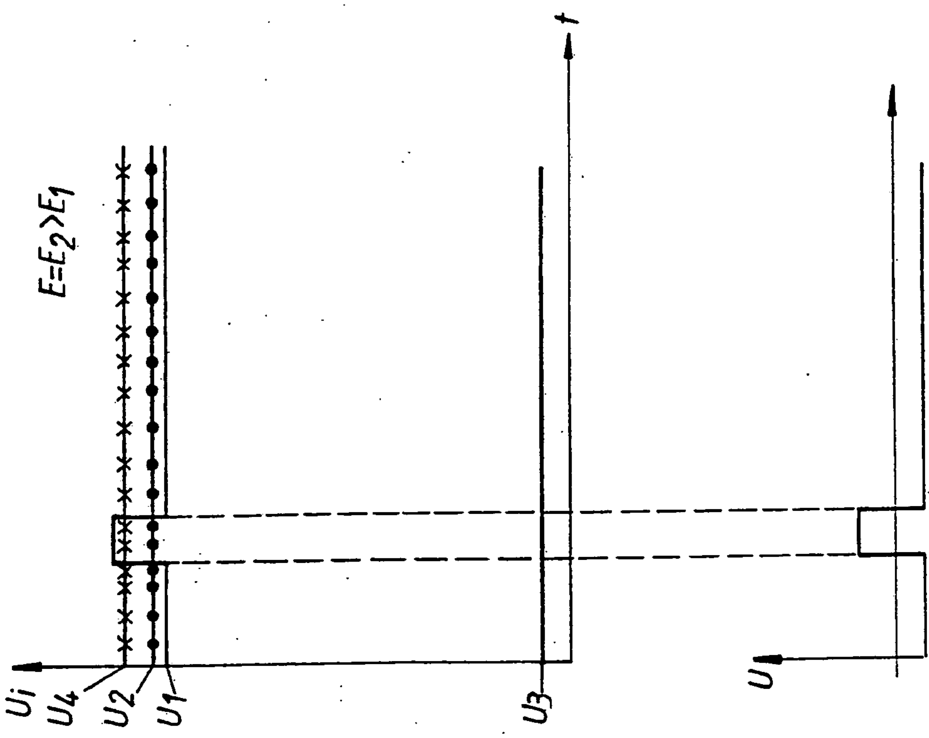

FIG.3.

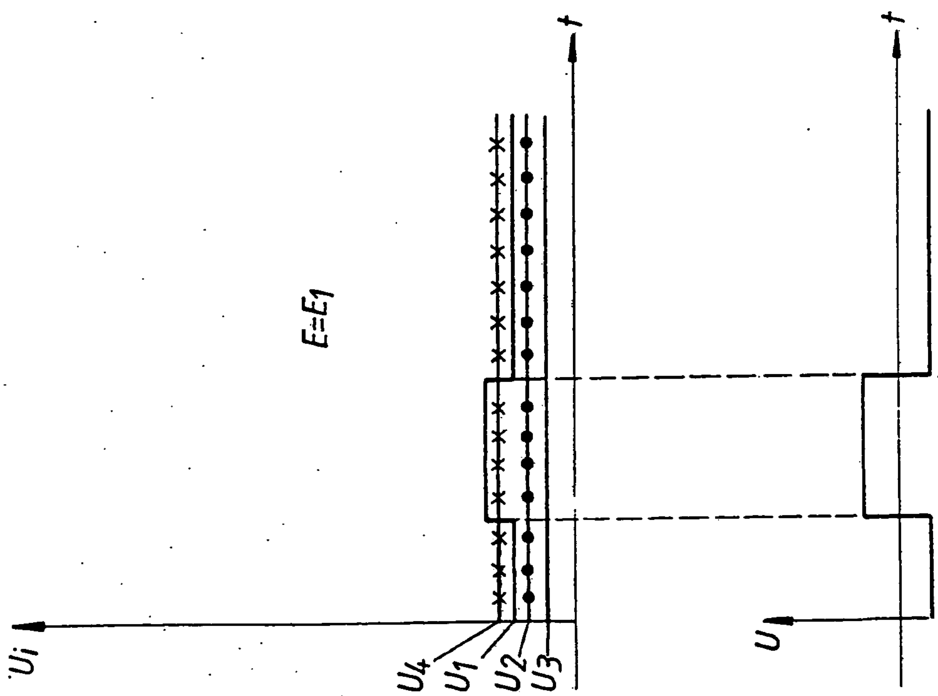

FIG.2.

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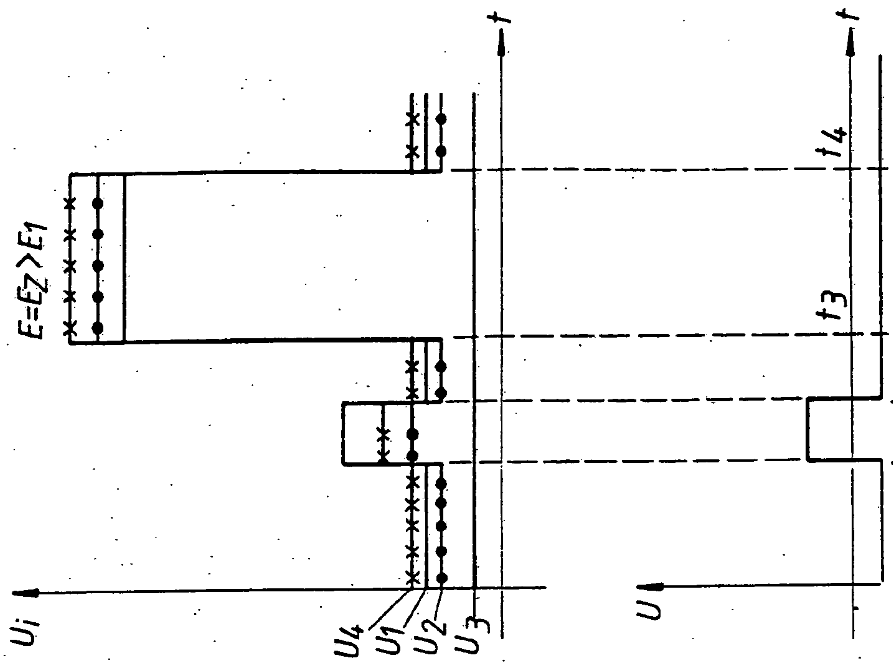

FIG.5.

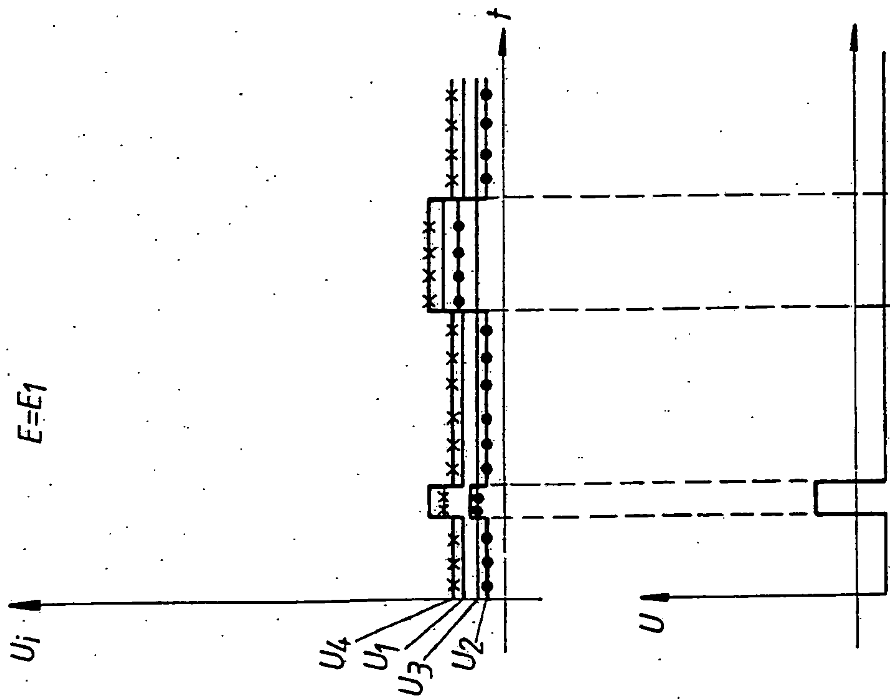

FIG.4.

COLOUR SENSOR AND METHOD FOR USE THEREOF

This invention relates to a colour sensor device and to its use in, inter alia, crop identification in agriculture.

A colour sensor known from USSR Patent Specification No.968631 contains a luminaire comprising a reflector fixed to a colour sensitive block containing optical filters, spectral separation element and photodetectors optically connected thereto for detecting radiation in the visible part of the spectrum and the adjacent infrared part of the spectrum belonging to the light signal reflected from the objects in the reflection zone. The outputs of the photodetectors are connected by logarithmic amplifiers to the inputs of a differential amplifier, the output of which is coupled to the input of a signal separation circuit the output of which is the sensor output and which is generally associated with means for storing and/or displaying the sensor output.

The disadvantage of the known colour sensor is its unstable operation resulting in unreliable identification of green crops occupying areas under 1.5 cm^2 and whose presence indicates a change from the soil being scanned and in local climatic and ambient conditions.

According to this invention there is provided a colour sensor apparatus which comprises a luminaire having a reflector attached to a colour sensitive block containing a light separation element, and, optically connected thereto, photodetectors for detecting respectively radiation in the visible part of the spectrum and in the infrared part of the spectrum adjacent the visible part from light reflected by objects in the zone of viewing, the outputs of which photodetectors are connected through respective amplifiers to the inputs of a comparator unit whose output is the output of the colour sensor, which amplifiers are linear with the linear amplifier in a channel for the visible part of the spectrum being

connected to a respective input of the comparator unit through an adder whose second input is connected to a DC voltage source.

This invention also provides a method of scanning an area of terrain for the presence of a crop which comprises operating over the terrain a colour sensor apparatus according to the invention with a beam of light projected from a light source to be reflected to the luminaire which is operated in association with the DC voltage source whose output is such that the polarity of the colour sensor is always positive when radiation reflected from a plant is being detected and is always negative when radiation from soil and/or rock is being detected.

For reasons which will be more fully appreciated hereinafter, the colour sensor according to this invention provides improved stability in recognising green crops on areas under 1.5 cm^2 when the soil and climatic conditions and the external prevailing light intensity (luminance) change.

For a better understanding of the invention and to show how the same can be carried into effect, reference will now be made by way of example only to the accompanying drawings, wherein:

FIGURE 1 is a block diagram of the circuitry of a sensor embodying this invention;

FIGURE 2 is a diagram of the voltages at the characteristic points of the block circuitry in Figure 1 expressed as a time function when the sensor is in operation over light-coloured soil at low prevailing light intensity E_1,

FIGURE 3 is a like voltage diagram of the voltages at the characteristic points 1 to 4, in Figure 1 when the sensor is in operation over light-coloured soil at high prevailing light intensity $E_2 > E_1$.:

FIGURE 4 is a diagram of the same voltages when the sensor operates over a dark-coloured soil at low

prevailing light intensity E_1, and

FIGURE 5 is a voltage diagram when the sensor operates over dark-colour soil and high prevailing light intensity $E_2 > E_1$.

The colour sensor of Figure 1 has a colour sensitive block 1 in which an optical channel 2 is formed which ends with a spectrum dividing element 3 optically connected to a solid state photodetector 5 for the visible part of the spectrum of the light signal reflected from an object 6 in the zone of reflection and to a solid state photodetector 4 for the adjacent infrared part of the spectrum. The output from the photodetector 4 for the infrared part of the reflected light signal adjacent the visible part is connected to the input of a linear amplifier 7. The output of the photodetector 5 for the visible part of the reflected light signal is connected to the input of a second linear amplifier 8, the output of which is connected to one of the inputs of an adder 9. A DC source 10 is connected to the other input adder 9. The outputs of amplifier 7 and adder 9 are connected to the two inputs of a comparator unit 11 the output of which is the output of the colour sensor. A light source 12 which has a reflector having its opening to objects 6 located in its field of view or vision zone is attached to the colour sensitive block 1.

The colour sensor operates as follows:-

Light from the light source 12 falls on objects 6 found in the vision zone viewed by the colour sensor. Light reflected by such objects is received by optical channel 2 and divided into two parts by the spectrum dividing element 3. The part of the reflected light corresponding to the visible part of the spectrum passes to photodetector 5, and the remaining part of the reflected light, corresponding to the adjacent infrared part of the spectrum, passes to photodetector 4.

The thus photodetected electromagnetic radiation is converted by photodetectors 4 and 5 into electrical

signals. These are amplified by the respective linear amplifiers 7 and 8 from the outputs of which are received the respective signals U_1 and U_2. A signal U_3 from the DC voltage source 10 is fed to one of the inputs of adder 9 at whose other input is received signal U_2 from the linear amplifier 8. A resultant signal U_4 thus appears across the adder 9 output and passes to one of the inputs of the comparator unit 11. Signal U_1 from the output of linear amplifier 7 is fed across the other input of the comparator unit 11. A signal which depends on the nature of the object 6, is formed at the output from the light sensitive block 1 after comparison of signals U_1 and U_4, the polarity of which signal changes when a plant (crop) falls in the viewing area of the colour sensor.

Figures 2 to 5 are voltage diagrams explaining the operation of the sensor under different conditions. Time is always plotted on the abscisse.

DC voltage U_3 from the DC voltage source 10 is the same regardless of any change in the soil and in climatic conditions.

When the colour sensor operates above the light coloured soils under low prevailing light intensity E_1 (Figure 2), the U_1 signal across the output of amplifier 7 in the channel for the infrared part of the spectrum adjacent the visible part is always larger than signal U_2 across the output of amplifier 8 in the channel for the visible part of the spectrum. The U_4 signal across the output of adder 9 is always larger than signal U_1, as a result of which output signal U is negative when there is no plant (crop) in the viewing area of the sensor. If at moment t_1 a plant falls within the sensor viewing area, the spectral make up of the signal reflected by the objects 6 will change in such a way that signal U_1 will increase sharply and become larger than signal U_4. This will result in a change of the sign for the output of the comparator unit 11, i.e. U_{otP} shall become positive. The positive resultant potential U will be maintained until

moment t_2 when the plant (crop) leaves the sensor viewing area.

With a value for the prevailing light intensity $E_2 > E_1$, changes in objects 6 in the viewing area of the sensor will as shown in Figure 3 result in increases in output signals U_1 and U_2 of amplifiers 7 and 8 in the two channels. The output signal U_4 of adder 9 also increases correspondingly. If there is no plant in the viewing area of the sensor, signal U_2 across the amplifier output in the channel for the visible part of the spectrum is larger than signal U_1 across the output of amplifier 7 in the channel for the adjacent infrared part of the spectrum. This is due to a change of the spectral composition of the light falling on objects 6. Signal U_4 is also bigger than signal U_1. Under these conditions the output signal U_{otp} from the comparator unit 11 is negative and is preserved until moment t_1 when a plant falls in the viewing area of the sensor. There is then sharp increase in signal U_1 which exceeds signal U_4, and this in turn results in the production of a positive signal U. The positive signal across the output of the comparator unit 11 is preserved until moment t_2 when the plant (crop) leaves the viewing area of the sensor.

When the colour sensor operates over light-colour soils as in the cases of Figures 2 and 3, any appearance and disappearance of rocks and stones in the viewing area of the sensor does not have any bearing on the output signal U of comparator unit 11 because the spectral reflective characteristics of the rocks and stones is identical to the spectral reflective characteristics of the light-coloured soil.

When the colour sensor operates over dark coloured soils, however, and there is no plant in the viewing area of the sensor, the ambient prevailing light intensity being low, then as shown in Figure 4, the output signal U_1 of amplifier 7 in the channel for the infrared part of the spectrum adjacent the visible part is always bigger

than signal U_2 across the output amplifier 8 in the channel for the visible part of the spectrum which is subject to the spectral reflective characteristics of the dark coloured soils. Under these conditions, signal U_3 from the DC source 10 is bigger than signal U_2, signal U_3 being sufficiently large for signal U_4 to be larger than signal U_1 so that the output signal U of the comparator unit 11 is negative; this is then a signal for the lack of any plant (crop). If a plant enters the viewing area of the sensor at moment t_1, it causes a marked increase in signal U_1 in the channel for the infrared part of the spectrum adjacent the visible part and U_1 becomes greater than signal U_4 across the output of adder 9, thereby causing a change of U from negative into positive. Although the value of U_2 has increased, its effect on U_4 is relatively small in relation to the increase in U_1. The positive value of U is preserved until moment t_2 when the plant leaves the viewing area of the sensor. If at moment t_3 a rock or stone, the spectral reflective characteristics of which are identical with those of light coloured soil, enters the viewing area of the sensor, signals U_1 and U_2 increase, with the increase in U_2 being particularly marked. Hence U_4 increases simultaneously to a marked extent and the inequality $U_1 < U_4$ is always preserved so that the negative signal U which is a signal for the absence of a plant is preserved across the output of comparator unit 11.

Finally, when the colour sensor operates over dark coloured soils with the ambient prevailing light intensity being high, i.e. $E_2 > E_1$, when there is no plant in the viewing area of the sensor, not only will the output signal U_1 of amplifier 7 in the channel for the infrared part of the spectrum adjacent the visible part will always be bigger than the signal U_2 across the output of amplifier 8 in the channel for the visible part of the spectrum which is subject to the spectral reflective characteristics of the dark coloured soil, but signal U_2

will nevertheless be greater than signal U_3 due to the DC voltage source 10. Signal U_4 will be greater than signal U_1, indeed, to a greater extent than in Figure 4. However, as previously described in connection with Figures 2 to 4, in the absence of any plant, the output signal U of the comparator unit 11 is negative. If a plant enters the viewing area of the sensor at moment t_1, it causes a marked increase in signal U_2 and an even greater increase in signal U_1 with U_1 becoming greater than signal U_4 across the output of adder 9, thereby causing a change of U from negative to positive. The positive value of U is preserved until moment t_2 when the plant leaves the viewing area of the sensor. If at moment t_3, a rock or stone, the spectral reflective characteristics of which are identical with those of light-coloured soil, enters the viewing area of the sensor, signals U_1 and U_2 both increase considerably but with signal U_2 increasing to a level higher than that of signal U_1. U_4 increases simultaneously, but the inequality $U_1 < U_4$ is always preserved so that the negative signal U which is a signal for the absence of a plant is preserved across the output of comparator unit 11.

As will be seen from the foregoing, when the colour sensor thus operates over dark-coloured soils as in the case of Figures 4 and 5, although, in contrast to passage over light-coloured soils, the sensor produces signals in response to the presence of the rocks or stones, any appearance and disappearance of rocks and stones in the viewing area of the sensor does not have any bearing on the polarity of output signal U of comparator 11. Thus the colour sensor apparatus of the invention provides a reliable indication of the presence of crops when used over either light-coloured soil or dark-coloured soils irrespective of the presence of rocks or stones in the soil.

Claims:

1. A colour sensor apparatus which comprises a luminaire having a reflector attached to a colour sensitive block containing a light separation element, and, optically connected thereto, photodetectors for detecting respectively radiation in the visible part of the spectrum and in the infrared part of the spectrum adjacent the visible part from light reflected by objects in the zone of viewing, the outputs of which photodetectors are connected through respective amplifiers to the inputs of a comparator unit whose output is the output of the colour sensor, which amplifiers are linear with the linear amplifier in a channel for the visible part of the spectrum being connected to a respective input of the comparator unit through an adder whose second input is connected to a DC voltage source.

2. A colour sensor apparatus as claimed in claim 1, wherein the output from the comparator is connected to signal recording means.

3. A colour sensor apparatus, substantially as hereinbefore described with reference to and as shown in, Figure 1 of the accompanying drawings.

4. A method of scanning an area of terrain for the presence of a crop which comprises operating over the terrain a colour sensor apparatus as claimed in any one of the preceding claims with a beam of light projected from a light source to be reflected to the luminaire which is operated in association with the DC voltage source whose output is such that the polarity of the colour sensor is always positive when radiation reflected from a plant is being detected and is always negative when radiation from soil and/or rock is being detected.

5. A method as claimed in claim 4, substantially as described herein with reference to the accompanying drawings.

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